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Experimental approach to seismic wave attenuation in partially molten material by using a cyclic deformation apparatus

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3D structure of seismic wave attenuation (Q^{-1}) has been mostly interpreted in terms of temperature inhomogeneity in the Earth interior. However, high ${Q_P}^{-1}$ is observed beneath subduction zones and oceanic ridges, where partial melting is expected to occur. ${Q_P}^{-1}$ may be interpreted not only as high temperature but also as partial melting. In order to investigate the effect of partial melting on the seismic wave attenuation, we have developed a cyclic deformation apparatus to measure the anelastic properties of melt-free and partially molten rock analogue.

The characteristics of the apparatus are summarized as follows [Fujisawa and Takei, 2006 JPGU].

(1) A uniaxial load is applied to a sample, and Q^{-1} for the uniaxial deformation is measured. (2) The sinusoidal load at the frequency of 0.1 mHz - 100 Hz is applied by using a piezoelectric actuator and monitored by a load cell. (3) The strain amplitude is 10^{-5}. Displacement of the sample (80 mm height) is measured by using a laser displacement meter with a resolution of 10^{-8} m. At this small strain, the measured data are not affected by crack opening and sample non-linearity. (4) Q^{-1} is determined from the phase lag between the stress and the strain of the sample. (5) In the preliminary run, Q^{-1} of the acrylic plastic samples was measured within the error of 0.002. The measured Q^{-1} and independently measured dispersion of Young modulus were consistent, indicating the reliability of the data.

Melt-free and partially molten rock analogue samples are made by using a binary eutectic system of organic polycrystal materials (borneol and diphenylamine, eutectic temperature = 43^{O}C). Melt-free samples are made of borneol. The dihedral angle is controlled in the range from 35^{O} to 17^{O}, close to that of rock + melt systems [Takei, 2000]. The experiments are conducted in a constant temperature chamber.

Q^{-1} of the melt-free samples were successfully measured at 20^{O}C - 60^{O}C. Q^{-1} was 0.01 - 0.05. Q^{-1} increased monotonically with decreasing frequency. The data is approximated as $Q^{-1} = 0.020*f^{-0.18}$ (f: frequency) at 60^{O}C. The value of the power increases with increasing temperature. The data for the melt-free samples are to be compared to the data of partially molten samples obtained in near future.

Grain boundary sliding mechanism has been expected to cause internal friction in the seismic frequency range. In order to investigate the magnitude of Q^{-1} caused by this mechanism, we theoretically calculated the relaxation strength of the grain boundary sliding for the melt-free and melt-bearing system. The integral of Q^{-1} over all frequency is called relaxation strength. The unrelaxed moduli were calculated by using the model of Takei [1998], and the relaxed moduli were calculated by modifying this model by considering relaxation of shear stress at the grain boundaries. For both melt-free and melt-bearing systems, the relaxation strength for bulk component is much smaller than that for shear component, indicating that ${Q_P}^{-1}$ is controlled by only shear component of internal friction.